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TECHNICAL DIVISION
SAVANNAH RIVER LABORATORY

DPST-73-280

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M E M O R A N D U M

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MATHEMATICAL MODEL FOR REACTOR BLANKET GAS SYSTEM

INTRODUCTION

In the event of a reactor accident in which voids are generated in the reactor tank, fluid will flow into the blanket gas system and a change in the system overpressure will occur. It is important to know the overpressure because of its major influence on the reactor transient. An existing rudimentary overpressure model in STEAM IIA has served to illustrate the importance of the overpressure calculation. Accordingly, a study was made of the reactor blanket gas system and a refined mathematical model was developed to give more exact prediction of overpressure.

SUMMARY

The blanket gas systems of K, C, and P reactors were studied in detail and a model was developed for overpressure calculations in reactor transient analysis codes. The necessary system of

equations and solution technique are presented for computer solution of the equivalent blanket gas system used in the model. Information is also presented on the reactor overflow system, automatic make-up and venting, and vacuum breaker design for pressure release considerations. This information supplements information presented in DPST-73-265.

DISCUSSION

Equivalent Blanket Gas System

The reactor blanket gas system drawings were studied for K, C, and P reactors to determine the system design, and equipment details. The reference drawing numbers are listed in Table I. Isometric diagrams of the key features of K Area are shown in Figures 1 through 4; other areas are similar. The equivalent length and diameter and the appropriate actual lengths of pipes were determined for each section of the major parts of the blanket gas system. The equivalent system diagram used in the model is shown in Figure 5 with a key for reference to various parts of the actual system. The applicable constants for use with Figure 5 are given in Table II.

The calculated volumes of the blanket gas system range from ~565 to 619 ~~640~~ ft3. These volumes are larger than those reported in DPSOL 765 which gives the volume of K and C reactors systems as 270 ft^3 and P reactor system as 310 ft^3. The volumes given in DPSOL do not include the volumes in the overflow tank, drain tank, associated piping, and the gas room. The system volumes calculated for this report include only one gas room as proposed new operating procedure requires the non-operated gas room to be isolated from the system.

Flow Equations

In the blanket gas system, compression of gas in the gas plenum due to a void formation in the tank, would cause helium to flow out to other parts of the system. This helium flow will cause a pressure drop which is responsible for system pressure gradients during a reactor transient. Two types of losses contribute to the system transient ΔP: (1) friction and kinetic losses and (2) acceleration losses. The equation for friction and kinetic losses for helium at about 50°C is

$$\Delta P_{f,k} = 1.032 \times 10^{-4} \rho \frac{V^{1.95}}{De^{1.2}} Le$$

where

$\Delta P_{f,k}$ = pressure drop, psid

ρ = density of helium, lbs/ft^3

V = fluid velocity, ft/sec

De = equivalent pipe diameter, inches

Le = equivalent pipe length, ft

The equation for acceleration losses in finite time step form is

$$\Delta P_a = \frac{\rho \; La}{144 \; g_c \; \Delta t} (V_i - V_{i-1})$$

where La = actual length of pipe of uniform diameter, ft

g_c = acceleration due to gravity, 32.17 ft/sec^2

Δt = time step, seconds

V_i = velocity at present time step, ft/sec

V_{i-1} = velocity at previous time step, ft/sec

and other symbols are as previously indicated.

A satisfactory approximation for helium density is

$$\rho = 0.638 \times 10^{-3}(P)$$

where P = pressure, psia

ρ = helium density, lbs/ft^3

The total pressure drop along a pipe is

$$\Delta P_T = \Delta P_{f,k} + \Delta P_a$$

Given the velocity of fluid movement through the pipe, the mass of fluid moving into and out of the various volumes can be calculated. Given the quantity of gas mass in each volume, the average gas pressure within a volume can be calculated by the ideal gas law:

$$P = \frac{m \quad (RT)}{Y}$$

where

P = pressure, psia

m = gas mass, lb-mole

RT = gas constant times temperature ($\sim$ 6000 at 50°C)

Y = volume, ft^3

One method of setting up and solving the system of equations for the blanket gas system is presented in the Appendix. This method requires three simplifying assumptions as discussed therein but is judged a practical approach.

Reactor Overflow System

The reactor is maintained at a constant level by means of an overflow system, Figure 1 and 3. D_2O is constantly supplied to the moderator system and allowed to overflow a weir located near the top of the reactor. Blanket gas is maintained above the liquid level. The overflow D_2O flows out the overflow pipe to a large "U" pipe section which remains full at all times. The D_2O then flows to the overflow tank. The "U" pipe section prevents gas from flowing directly to the overflow tank.

The amount of D_2O overflow required during a reactor transient is determined by the D_2O addition rate (normally $\sim$ 40 gpm) and the void generation rate. The overflow rate is determined by the liquid level plus the weir and overflow pipe design. Thus an increased fluid volume in the reactor tank will cause the liquid level to rise and increase the overflow rate. After the liquid overflow level is raised more than $\sim$ 1 to 1½ inches, overflow is limited by available head and resistance between the weir and "U" pipe section. More overflow could be obtained if a syphon could develop but it is unlikely that one would develop very quickly because of the long drop into the overflow tank. Table III lists the maximum net gravity overflow rates for K, C, and P reactors with and without a syphon effect. At void generation rates above these maximum overflow rates, the gas plenum will fill with liquid until the liquid is forced out the vacuum breaker and gas inlet and outlet pipes. At overflow rates below the maximum value, a new equilibrium level will be established as determined by the following formula of the weir characteristics:

$$Q = 3.3\ (4 - 0.2H)\ H^{1.5}$$

where Q = overflow rate, ft^3/sec

H = liquid level above top of weir, ft

If a differential gas pressure develops between the gas plenum and overflow tank, additional liquid flow can develop between the two but the circumstances of such an event indicate that the effect is unimportant.

Vacuum Breaker

The essential details of the vacuum breaker pot are shown in Figure 6. Release of gas can occur by either of two methods termed 1st and 2nd stage release. First stage release occurs when the water level drops ~ 3 inches below normal to expose the 1/2-inch pipe in the side of the standpipe. Second stage release occurs when the water level drops 4 inches below normal to permit gas to pass under the slots into the standpipe. The various conditions and effect of 1st and 2nd stage release are summarized in Table IV. The applicable equations needed to calculate the mass release rate are given in Table V and DPST-72-581.

Automatic Gas Makeup and Venting

The blanket gas system is maintained at about 5.0 psig by an automatic system that will vent or make up gas as needed. Both the vent and make-up point are located downstream of the gas room. The automatic venting will occur with system pressure equal or greater than 5.3 psig. Automatic make up will occur if the system pressure drops to 4.9 psig. The make up and vent rate is reported as ~ 11 scfm*.

Gas Plenum Liquid Overflow

In the event of a reactor transient in which all the gas plenum space is filled with liquid, continued volume increase in the reactor tank will cause liquid to flow out the vacuum breaker, reactor standpipes, and gas lines. Steady state treatment of outflow through the vacuum breaker and standpipe is presented in DPST-72-544. Transient treatment requires the addition of the acceleration pressure losses.

Liquid flow through the gas pipes can be estimated from the information presented herein for the blanket gas system. The friction and kinetic losses for D_2O flow (at 50°C) in the blanket gas system pipe is

$$\Delta P_{f,k} = 2.78 \times 10^{-3} \frac{V^{1.95}}{D_e^{1.2}} L_e$$

*DPSP-64-1-2R, Reactor Technology Monthly Report, February, 1964.

where the nomenclature is as previously indicated. The acceleration pressure loss equation is identical to that previously presented. Total pressure losses are equal to the summation of losses from each contribution. To calculate the ΔP, one must know the applicable equivalent length and liquid velocity. An iterative program solution similar to that developed for the gas system is required for this calculation. The flows will probably be relatively low and therefore an estimate of the flow should be sufficient. The flow to the gas pipe can be assumed; the applicable L_e can be estimated from the ratio of liquid volume in the pipe to the total volume times the L_e of the pipe section; then with the appropriate D_e for the pipe section, the pressure drop can be calculated from the above equation. A pressure drop within 20% of the pressure drop in the important parallel flow path (vacuum breakers) would be sufficient. The model of Figure 1-A should be used.

Miscellaneous Consideration

The effect of the gas circulation blower on system pressure is negligible because it has a rated ΔP at full flow of 1.5 inches H_2O.

The gas room can be treated as a long pipe because, although there is significant volume, there is high pressure drop and the resulting length to volume ratio is similar to other pipes in the blanket gas system.

TABLE I

REACTOR BLANKET GAS SYSTEM REFERENCE DRAWINGS

K-Area	C-Area	P-Area
W-134243	W-134387	W-131554
134251	134388	131721
134351	134407	131730
134360	134418	131774
134362	134977	131881
134381	134978	132460
134385	144456	143370
143904	160101	167108
143915	160136	167109
143916	160137	231138
S5-1-2880	160160	
D-110036	231160	
D-112522	D-113178	
D-136204	D-113328	

TABLE II

DATA FOR APPLICATION TO EQUIVALENT BLANKET GAS SYSTEM DIAGRAM*

	K Area				C Area				P Area			
Location*	Le, ft	La, ft	De, in.	Vol, ft^3	Le, ft	La, ft	De, in.	Vol, ft^3	Le, ft	La, ft	De, in.	Vol, ft^3
A	-	-	-	97	-	-	-	97	-	-	-	97
A-B	310	40	6	9.3	108	43	6	15.5	309	38	6	8.6
B-C	540	227	6	53	505	205	6	52	644	337	6	75
C-D**	740	150	6	90	740	150	6	90	740	150	6	90
D-A	760	300	6	65	528	275	6	72	916	425	6	94
B-E	331	200	4	119	455	245	6	160	262	142	4	129
E-F	75	38	2	0.9	59	22	2	0.5	76	30	2	0.7
[illegible]**	-	-	-	125	-	-	-	125	-	-	-	125
H	(Vent all 11 scfm for system pressure ≥ 5.3 psig, makeup at 11 scfm for system pressure ≤ 4.9 psig)											
J	(Venting based on pressure history)											

*See Figure 5.

**The purification system is similar for all areas and thus the same data were used for each area. It is assumed that only one gas room is operated and the second is isolated from the system.

***It was assumed the overflow tank is normally 60% full of D_2O and the remaining 40% contains gas.

TABLE III

MAXIMUM REACTOR OVERFLOW RATES*

Reactor	Max. Net Gravity Overflow Rate* with syphon ft^3/sec	without syphon ft^3/sec
K	0.78	0.66
C	0.85	0.53
P	0.77	0.60

*The net overflow rates are based on equal gas pressure in the gas plenum and overflow tank and normal overflow equal to 0.09 ft^3/sec (40 gpm).

Table IV

VACUUM BREAKER RELEASE CONDITIONS

1st Stage Release Conditions

- Initiated when makeup is less than displacement in vacuum breaker pot and water level drops ~ 3 inches below normal (see Figure 6). This could be a transient relief if the pressure did not continue to rise.

- Initiated any time gas pressure in plenum reaches 5.65 psig. This is the steady state pressure to maintain constant first stage venting.

- Requires 3 seconds after initiation to reach maximum venting rate of 20 scfm per vacuum breaker (There are two vacuum breakers on each reactor.)

- System will stop venting (1st stage) when pressure decreases and water level in pot rises above 1/2-inch pipe in side of standpipe.

- Conditions for 1st stage release are critical and perhaps unstable because total D_2O make-up (10 gpm) must flow out standpipe or 1/2-inch pipe while level in vacuum breaker pot is maintained within 1" inch of the bottom of the 1/2-inch pipe.

2nd Stage Release Conditions

- Initiated when makeup is less than displacement in vacuum breaker pot and water level drops 4.0 inches below normal

- Initiated any time gas pressure in plenum reaches 5.7 psig

- System will not recover from 2nd stage release once triggered and discharge rate is determined by vacuum breaker mathematical model (see Table V).

Table V

VACUUM BREAKER MATHEMATICAL MODEL

1st Stage Release

Beginning 3 seconds after initiation of 1st stage release

Maximum Outflow = 20 scfm/vacuum breaker
(40 scfm total)

2nd Stage Release (See DPST-72-581)

$$F = C_d \sqrt{\Delta P}$$

where F = gas mass outflow rate, #-mole/second

C_d = discharge coeff

ΔP = differential pressure, gas plenum to atmosphere, psid

C_d is defined by

$$C_d = \left[\frac{\sum_{t=0}^{t} \bar{P} \, \Delta t}{5.7} \right]^9 \times (0.05)$$

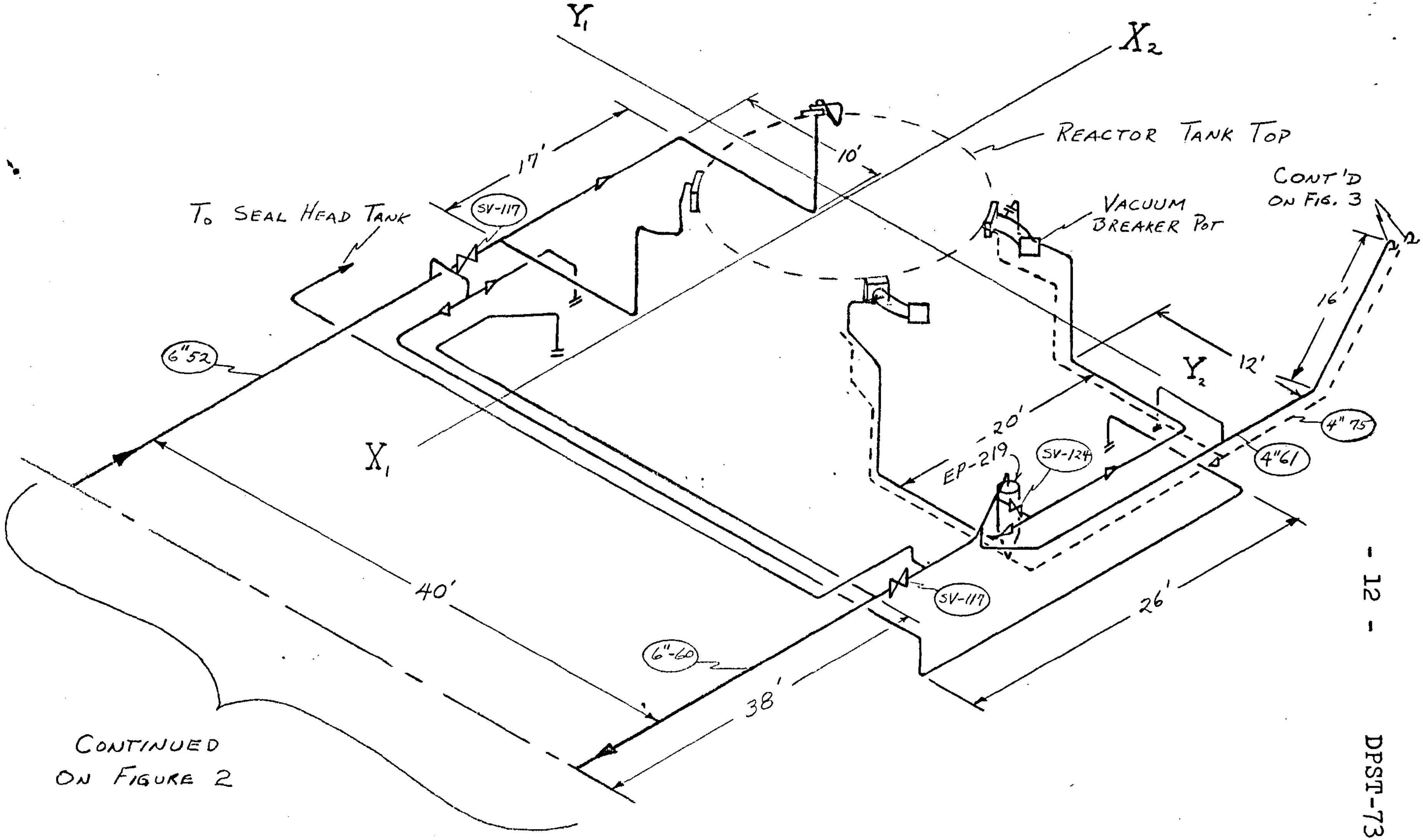
where t = time after triggering 2nd stage release

$\bar{P}$ = average pressure above 17.4 psia over time increment.

The maximum value of C_d = 0.675 when the standpipe is clear of water.

FIGURE 1

BLANKET GAS SYSTEM PIPING - ISOMETRIC DIAGRAM
(Reactor Room Area, K-Area)



Gas Line

Liquid Overflow Line

Line or Valve Number

FIGURE 2

BLANKET GAS SYSTEM PIPING - ISOMETRIC DIAGRAM
(Reactor Room to Gas Rooms, K-Area)

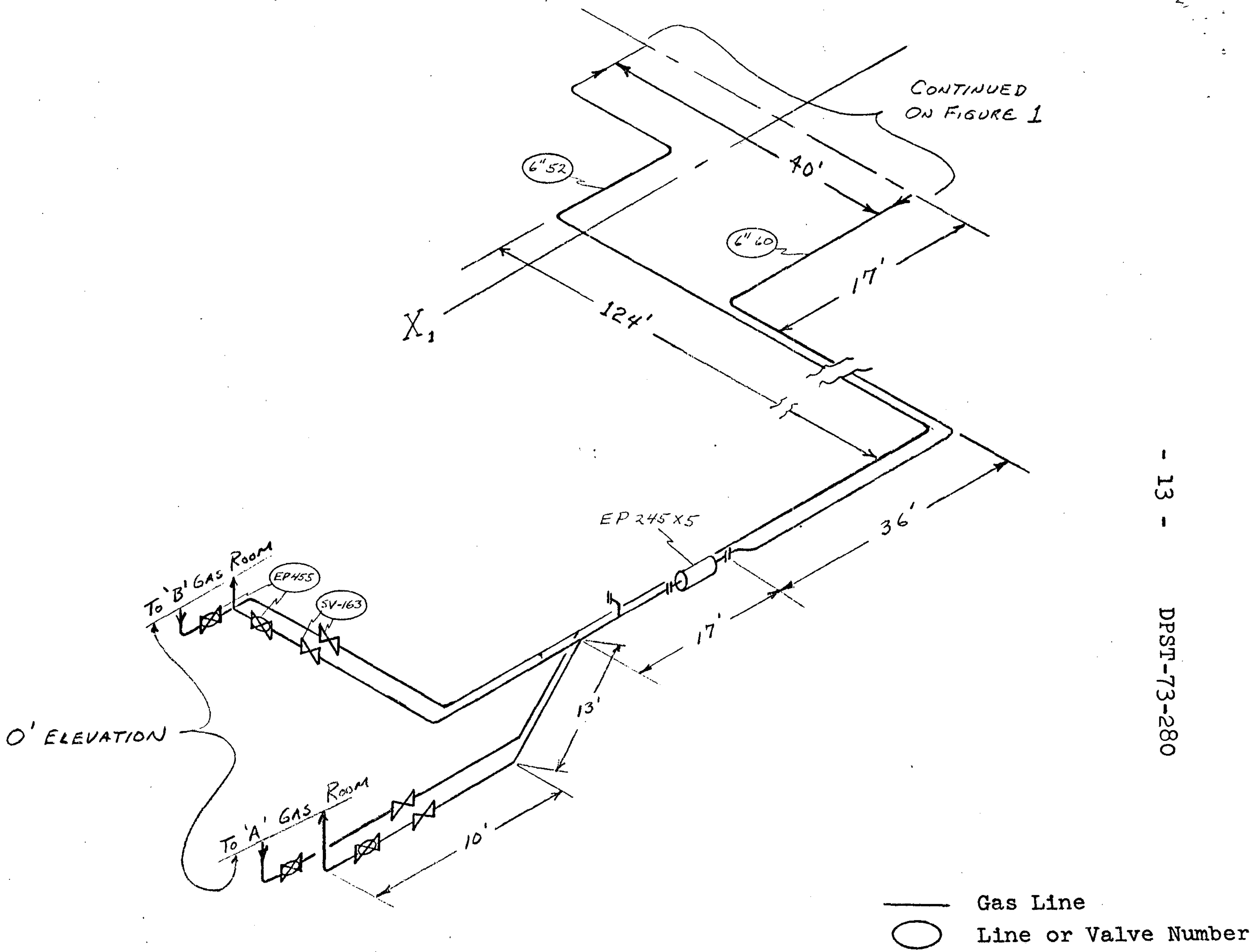


FIGURE 3

BLANKET GAS SYSTEM PIPING - ISOMETRIC DIAGRAM
(Reactor Room Area to Overflow Tank, K-Area)

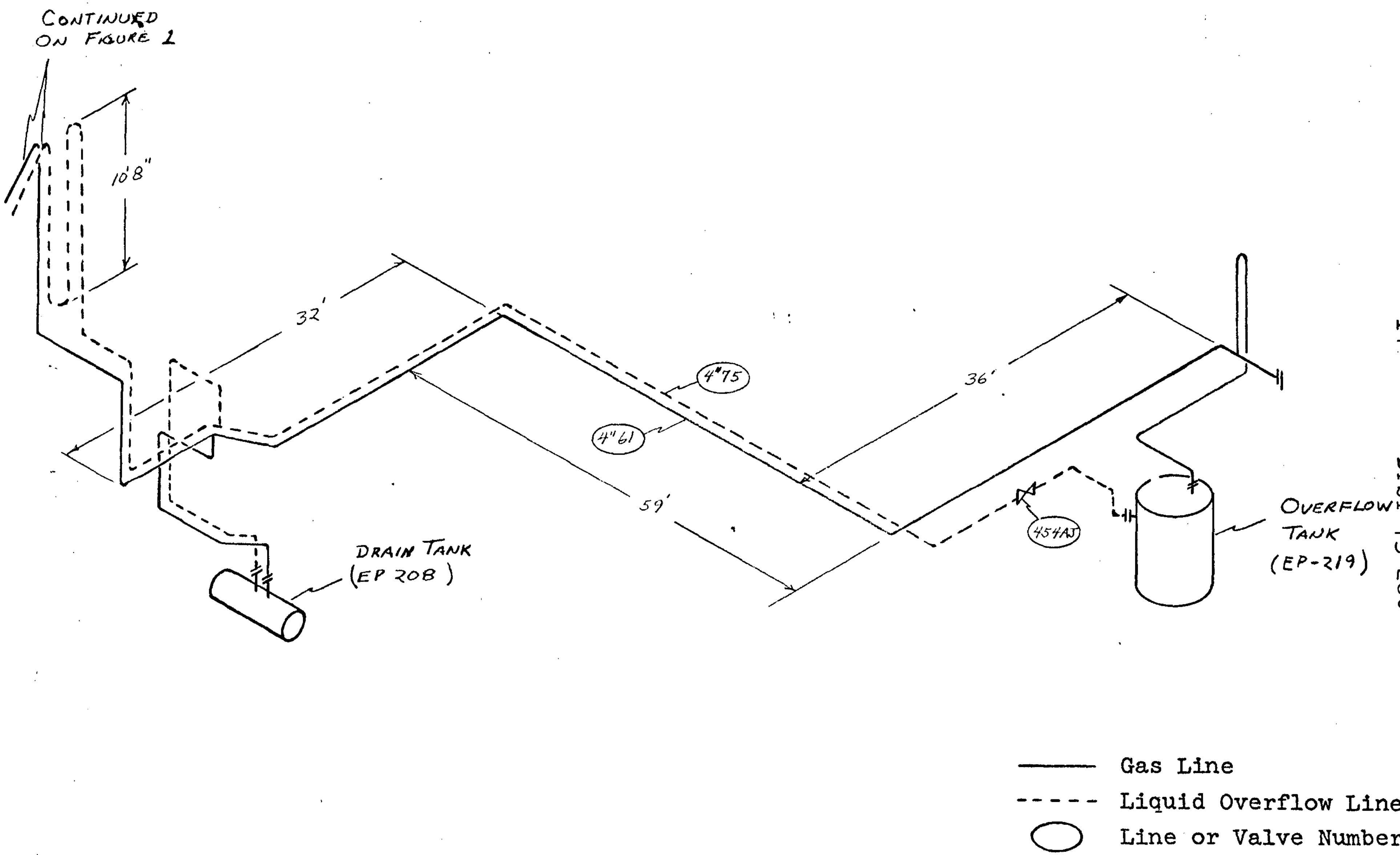


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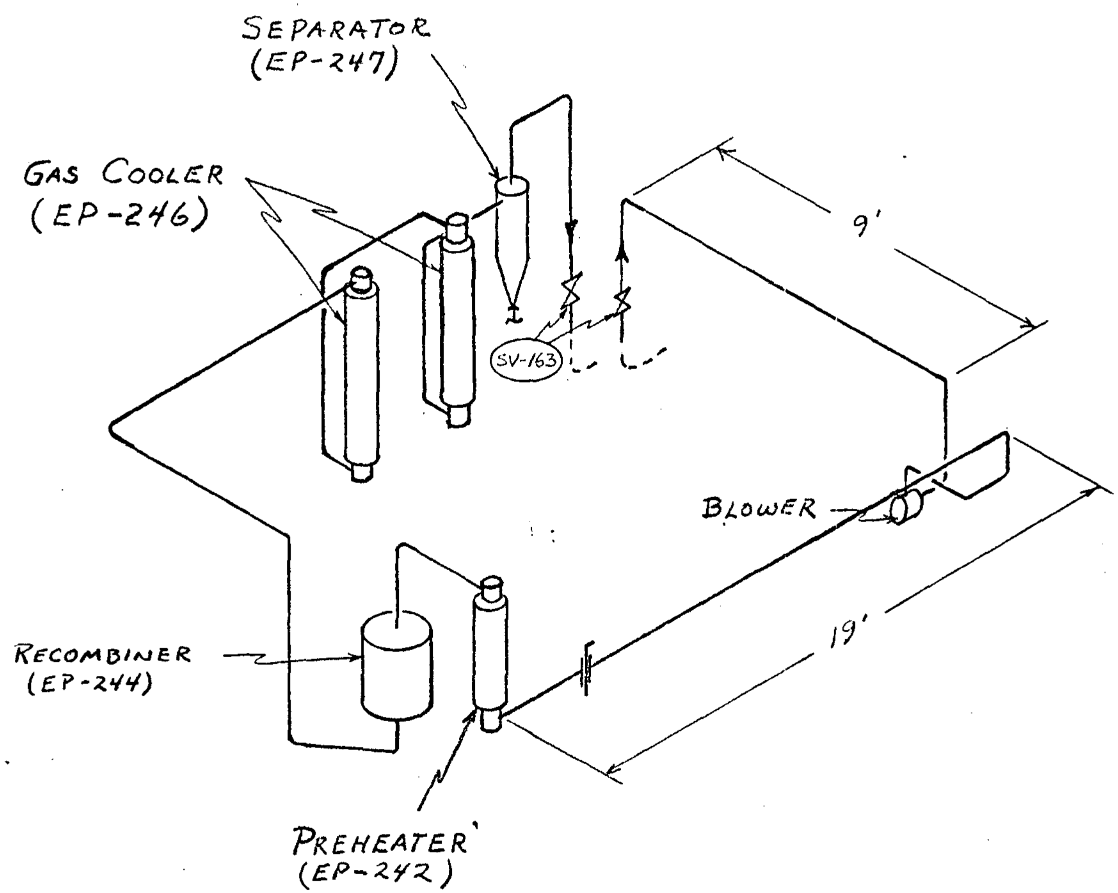
FIGURE 4

BLANKET GAS SYSTEM PIPING - ISOMETRIC DIAGRAM

('A' Gas Room, K-Area)

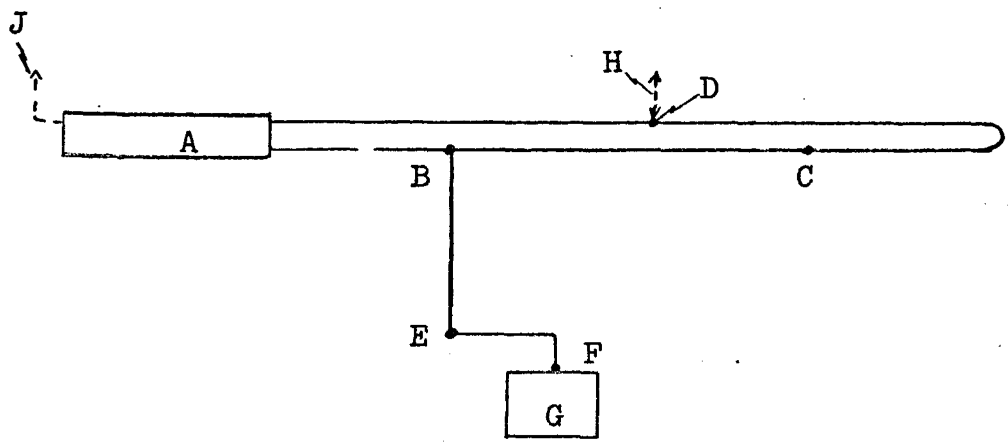


——— Gas Line

◯ Line or Valve Number

FIGURE 5

EQUIVALENT BLANKET GAS SYSTEM DIAGRAM

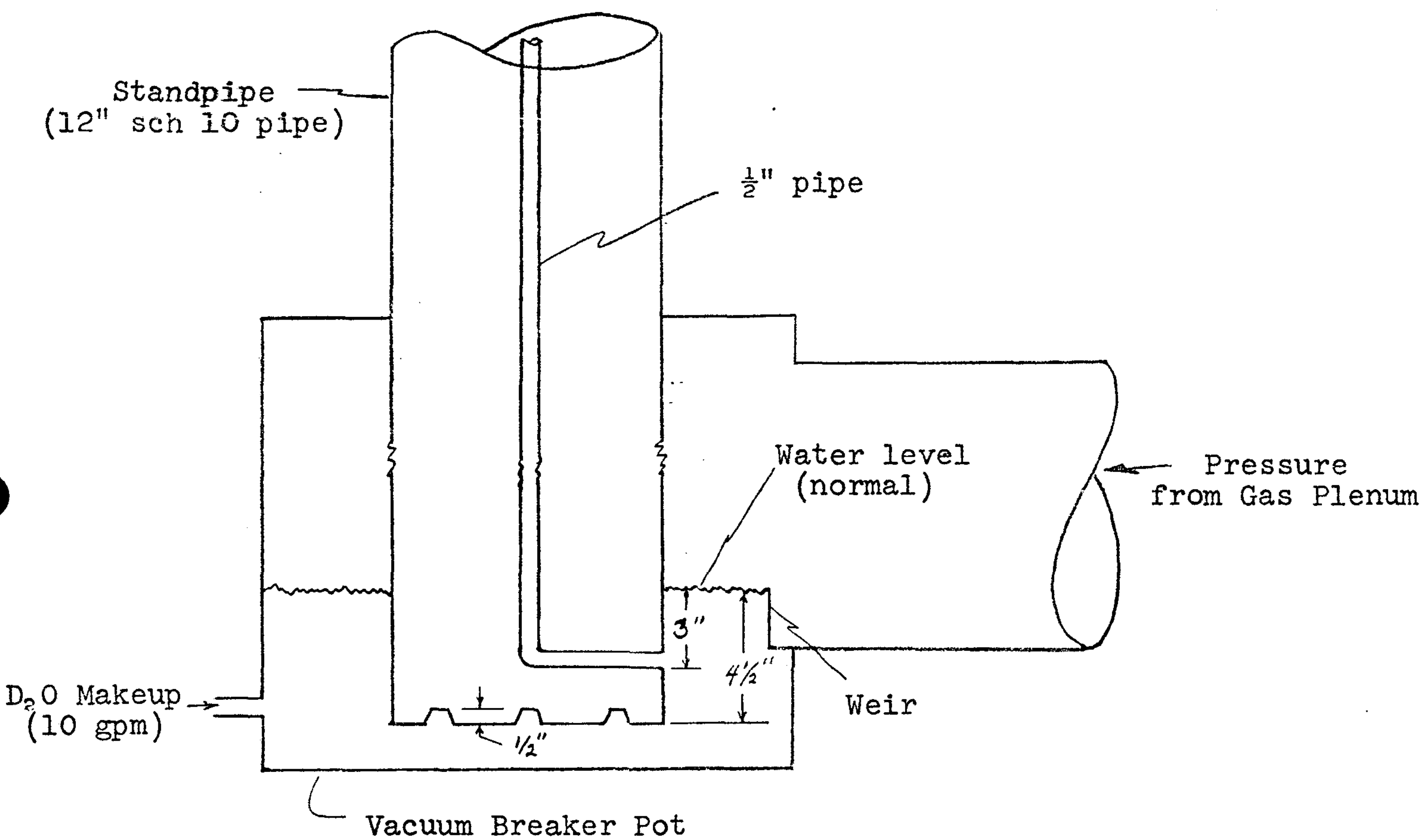


Reference Point	Blanket Gas System Component
A	Gas plenum in reactor
A-B	Gas plenum effluent line
B-C	Gas piping to purification gas room
C-D	Gas room
D-A	Return piping to gas plenum
B-E	Composite of miscellaneous piping, drain tank volume*, and main pipe to overflow tank
E-F	Small diameter pipe from main to overflow tank
G	Overflow tank*
H	Automatic makeup or vent depending on system pressure
J	Vacuum breaker

* Drain tank and overflow tank were assumed normally 28% and 60% full of D_2O, respectively, per a 30-day average in C Area.

FIGURE 6

VACUUM BREAKER POT DESIGN



APPENDIX

A SOLUTION TECHNIQUE FOR THE SIMPLIFIED BLANKET GAS SYSTEM PIPING NETWORK

The diagram of the blanket gas system shown in Figure 5 can be simplified further by making the following assumptions.

1. The pressure drop in pipe section B-E is much less than in pipe section E-F because of the difference in pipe diameters. Thus the total volume in section B-E can be assumed as a tank with no pressure drop due to flow across the tank.

2. The pipe sections B-C, C-D, and D-A can be combined so that one equation can be used to express the ΔP through this section. The equation for ΔP uses the average gas velocity in the section.

3. The pressure at point D (Figure 5), needed to determine automatic makeup or venting, can be calculated after the average velocity in section B-C-D-A is found and the pressure in the gas plenum is known.

The result of the above assumptions is to simplify the blanket gas system model as illustrated in Figure 1-A. It is this model on which a solution technique will be developed and to which reference is made unless otherwise noted. Note that reference points have been renumbered. The applicable data for figure 1-A is given in Table I-A.

Development of System Equations

The sign convention is that velocities in a clockwise direction around the loop (Figure 1-A) are positive. Also, velocities from B to G are positive and positive velocities produce a positive ΔP. The definition and units of the terms in the following equations are as presented in the text.

The ΔP's around the loop are:

$$\Delta P_{12} + \Delta P_{34} = 0 \qquad (1)$$

where

$$\Delta P_{12} = C_a \left| V_{12_i} \right|^{1.95} + C_b (V_{12_i} - V_{12_{i-1}}) \qquad (2)$$

$$\Delta P_{34} = C_c \left| V_{34_i} \right|^{1.95} + C_d (V_{34_i} - V_{34_{i-1}}) \qquad (3)$$

$$\Delta P_{56} = C_e \left| V_{56_i} \right|^{1.95} + C_f (V_{56_i} - V_{56_{i-1}}) \qquad (4)$$

and

i = present time step

$i-1$ = previous time step

Note that C_a, C_c or C_e must be assigned negative values if V_{12_i}, V_{34_i} or V_{56_i} are negative respectively.

The values of the constants are

$$C_a = C_c = C_e = \rho \frac{\Delta H}{144} = 1.032 \times 10^{-4} \rho \frac{Le}{D_e^{1.2}} \qquad (5)$$

and

$$C_b = C_d = C_f = \rho \frac{La}{144\ g_c} \Delta t$$

The solution must satisfy a mass balance, that is

$$m_T = m_A + m_{12} + m_{34} + m_B + m_{56} + m_G \qquad (7)$$

where the subscript denotes the gas mass in a particular section and m_T is the total system gas mass.

Note that

$$m = \frac{PY}{RT} \tag{8}$$

where

P = pressure, psia

Y = volume, ft^3

RT = gas constant at 50°C, $\sim 6000 \frac{ft^3}{in^2\text{-mole}}$

$$\therefore m_T = \frac{1}{RT}(P_A Y_A + P_{12} Y_{12} + P_{34} Y_{34} + P_B Y_B + P_{56} Y_{56} + P_G Y_G) \tag{9}$$

Simply by use of constants, that is

$$C_1 = \frac{Y_A}{RT}$$

$$C_2 = \frac{Y_{12}}{RT}$$

$$C_3 = \frac{Y_{34}}{RT}$$

$$C_4 = \frac{Y_B}{RT} \tag{10}$$

$$C_5 = \frac{Y_{56}}{RT}$$

$$C_6 = \frac{Y_G}{RT}$$

Also note

$$P_{12} = P_{34} = \frac{P_A + P_B}{2} \tag{11}$$

and

$$P_{56} = \frac{P_B + P_G}{2} \tag{12}$$

The mass of gas in B at the end of t_i is

$$m_{B_i} = m_{B_{i-1}} + \Delta m_2 - \Delta m_3 - \Delta m_5 = C_4 P_{B_i} \tag{13}$$

where

Δm_2, Δm_3, Δm_5 = mass crossing respective point into or out of volume B.

The mass crossing a boundry is defined as

$$m_{2_i} = \frac{P_{12_{i-1}} \; (A_p \; \Delta t \; \bar{V}_{12})}{RT} \tag{14}$$

where

$(A_p \Delta t \; \bar{V}_{12})$ = flow volume into volume B from volume 1-2 across point 2 in a time step, ft^3.

A_p = Pipe flow area, ft^3

Δt = time step, sec

V_{12} = avg. velocity in 1-2 over last time step, ft/sec

$$\bar{V}_{12} = \frac{V_{12_i} + V_{12_{i-1}}}{2}$$

Simplifying equation (14) with use of a constant D, we have

$$\Delta m_1 = \Delta m_2 = D_1 \; \bar{V}_{12}$$

$$\Delta m_3 = \Delta m_4 = D_2 \bar{V}_{34}$$

$$\Delta m_5 = \Delta m_6 = D_3 \; \bar{V}_{56} \tag{15}$$

The mass of gas in G at the end of t_i is

$$m_{G_i} = m_{G_{i-1}} + \Delta m_5 = C_6 \, P_{G_i} \tag{16}$$

with equation (15)

$$P_{G_i} = \frac{m_{C_{i-1}}}{C_6} + \frac{D_3 \, \bar{V}_{56}}{C_6} \tag{17}$$

The mass of gas in A at the end of t_i is

$$m_{A_i} = m_{A_{i-1}} + \Delta m_4 - \Delta m_1 = C_1 P_A$$

with eq (15)

$$P_{A_i} = \frac{m_{A_{i-1}}}{C_1} + \frac{D_2 \, \bar{V}_{34}}{C_1} - \frac{D_1 \, \bar{V}_{12}}{C_1} \tag{18}$$

Also from equations (13) and (15)

$$P_{B_i} = \frac{m_{B_{i-1}}}{C_4} + \frac{D_1}{C_4} \bar{V}_{12} - \frac{D_2}{C_4} \bar{V}_{34} - \frac{D_3}{C_4} \bar{V}_{56} \tag{19}$$

Note that

$$P_A = P_B + \Delta P_{12}$$

$$= P_B - \Delta P_{34}$$

and

$$P_G = P_B - \Delta P_{56}$$

Now substitute into equation (7) the masses in terms of P_B and the ΔP's

$$\therefore m_T = \underbrace{C_1(P_B - \Delta P_{34})}_{m_A} + \underbrace{C_2\left(\frac{P_B + \Delta P_{12} + P_B}{2}\right)}_{m_{12}} + \underbrace{C_3\left(\frac{P_B - \Delta P_{34} + P_B}{2}\right)}_{m_{34}}$$

$$+ \underbrace{C_4 P_B}_{m_B} + \underbrace{C_5\left(\frac{P_B - \Delta P_{56} + P_B}{2}\right)}_{m_{56}} + \underbrace{C_6(P_B - \Delta P_{56})}_{m_G} \tag{20}$$

where

P_B is defined by equation (19) and ΔP's are defined by equations (2), (3) and (4).

Equation (20) is the defining system equation with three unknowns, V_{12}, V_{34} and V_{56} as seen after substitution. Equation (20) can be solved by assuming two of the variables as constant and iterating on the third. The suggested iteration sequenced is from the most significant variable to the least significant. Accordingly, it is suggested that iteration begin with V_{34} for two cycles, then V_{12} for two cycles, followed by V_{56} for one cycle and then return to V_{34}. The latest value of all variables must be used in each iteration cycle. Iteration should continue until

$$m_T = m_T^{(k)} \pm \epsilon_1$$

and $$P_A - P_B = \Delta P_{12} \pm \epsilon_2$$

where

$m_T^{(k)}$ = valve of m_T from present iteration and

ϵ = acceptable error

A converging iteration technique for solution of the above equations is presented below. An alternate methodof solution is to convert equation (20) to a quadratic form for each of the variables. This can be easily done with small error by assuming the first term of the ΔP equations, (2), (3), and (4), is a function of V^2 instead of $V^{1.95}$. The error can be minimized by adjusting the respective coefficients, Ca, Cc, and Ce, so that the ΔP calculated by both forms of the equation are equal at the upper range of the expected velocities. After equation (20) is placed in quadratic form and solved for each variable velocity, the calculation sequence described above can be followed to a solution. A relaxation factor may be needed to help convergence. The advantage of this method is that the equation will calculate an exact solution for one varible if the other two varibles are assumed known. Thus iteration on a single variable is not necessary.

A Converging Iteration Technique

Equation (20) can probably be solved by the Newton-Rophson method although problems occurred in a similar application for negative values of the variables. The method requires taking the derivative of the system equation (20).

First, let

$$PNVK = 0 = m_T^{(K)} = m_T \tag{21}$$

Then take partial derivative with respect to each variable

$$\frac{\partial(PNVK)}{\partial V_{34}} = PPV34K = \frac{D_2}{2\ C_4}(C_1 + C_2 + C_3 + C_4 + C_5 + C_6) - C_1\ E_2 - \frac{C_3}{2}\ E_2 \tag{22}$$

$$\frac{\partial(PNVK)}{\partial V_{12}} = PPV12K = \frac{D_1}{2\ C_4}(C_1 + C_2 + C_3 + C_4 + C_5 + C_6) + \frac{C_2}{2}\ E_2 \tag{23}$$

$$\frac{\partial(PNVK)}{\partial V_{56}} = PPV56K = \frac{D_3}{2\ C_4}(C_1 + C_2 + C_3 + C_4 + C_5 + C_6) - \frac{C_5}{2}\ E_3 - C_6 E_3 \tag{24}$$

where

$$E_1 = 1.95\ C_a\ \left| V_{12} \right|_i^{0.95} + C_b \qquad (25)$$

$$E_2 = 1.95\ C_c\ \left| V_{34} \right|_i^{0.95} + C_d \qquad (26)$$

$$E_3 = 1.95\ C_e\ \left| V_{56} \right|_i^{0.95} + C_f \qquad (27)$$

The estimate of the new value for iteration is

$$V_{34}^{(K+1)} = V_{34}^{(K)} - \frac{PNVK}{PPV34K} \qquad (28)$$

$$V_{12}^{(K+1)} = V_{12}^{(K)} - \frac{PNVK}{PPV12K} \qquad (29)$$

$$V_{56}^{(K+1)} = V_{56}^{(K)} - \frac{PNVK}{PPV56K} \qquad (30)$$

where $V^{(K)}$ = value of V in present iteration

$V^{(K+1)}$ = new value of V for next iteration

Because of iteration on three variables in one equation, a relaxation coefficient may be necessary to ensure convergence. The essential features of the solution technique for equation (20) are diagramed in Table II-A.

Change in Gas System Total Mass

Assuming no component failure, the total gas mass in the blanket gas system can change depending on the system pressure. Gas release can occur at two points and make-up at one point. The vacuum breakers connected to the gas plenum is one source of gas loss depending on gas plenum pressure. The second source is the automatic vent and make-up located at point h, Figure 1-A.

The vacuum breaker design is shown in Figure 6, and the conditions for release given in Table IV. The mathematical model for gas release is given in Table V. The existing mathematical model of the vacuum breaker in STEAM IIA includes only the details for second-stage release, the logic for first-stage release must be programmed per Table IV. After calculation of the amount of gas mass released through the vacuum breaker during a time step, the total mass of gas in the plenum and in the system must be adjusted in equation (20) and (21). In equation (20), the adjustment applies only to the term for m_A.

The automatic vent and make-up can be handled in a manner similar to the vacuum breaker. That is after V_{12} is calculated,

$$P_h = P_A - \Delta P_h$$

and

$$\Delta P_h = C_{ah} \left| V_{12} \right|_i^{1.95} + C_{bh} \left(V_{12_i} - V_{12_{i-1}} \right)$$

where

$$C_{ah} = 1.032 \times 10^{-4} \rho \frac{L_{eh}}{D_e^{1.2}} \quad \text{and} \quad C_{bh} = \frac{\rho L_{ah}}{144 \, g_c \Delta t}$$

The values of L_{eh}, L_{ah} and D_{eh} are from Table II for pipe D to A.

After the pressure at P_h is calculated, venting or makeup can be determined by the following conditions.

a) If $P_h \geq 5.3$ psig (20.0 psia), vent at rate of 11 scfm.

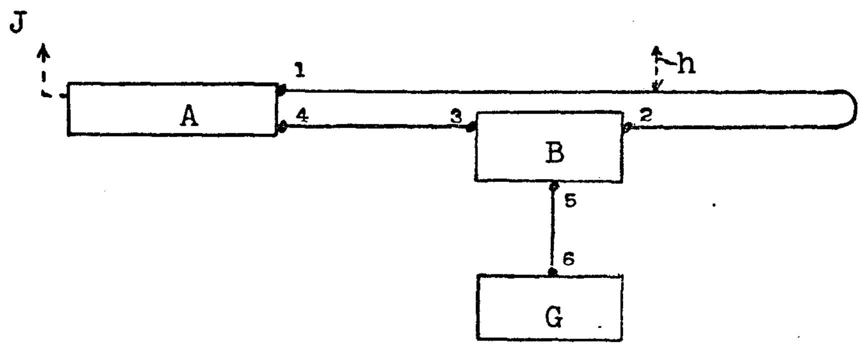
b) If $P_h \leq 4.9$ psig (19.6 psia), make-up at rate of 11 scfm.

Then calculate the total gas mass make-up or vented and adjust equations (20) and (21). In equation (20), the correction is applied to the term for m_{12}. The location of these corrections in the calculational sequence is shown in the diagram of Table II-A.

DRM:hi

FIGURE I-A

EQUIVALENT BLANKET GAS SYSTEM DIAGRAM
SIMPLIFIED BY ASSUMPTION OF APPENDIX



Reference Point	Blanket Gas System Component
A	Gas plenum
B	Equivalent volume of pipe and drain tank
G	Overflow tank
1-2, 3-4, 5-6	Piping

TABLE I-A

SYSTEM CONSTANTS FOR USE WITH MODEL OF FIGURE I-A

		K-Area				C-Area				P-Area			
Item	Location*	Le, ft	La, ft	De, in	Y, ft^3	Le, ft	La, ft	De, in	Y, ft^3	Le, ft	La, ft	De, in	Y, ft^3
Gas Plenum	A	-	-	-	97.0	-	-	-	97.0	-	-	-	97.0
Equivalent Volume	B	-	-	-	118.7	-	-	-	160.3	-	-	-	128.8
Overflow Tank	G	-	-	-	125.0	-	-	-	125.0	-	-	-	125.0
Piping	1-2	2040	677	6	208.6	1773	630	6	228.2	2300	912	6	269.0
Piping	3-4	310	40	6	9.3	108	43	6	15.5	309	38	6	8.6
Piping	5-6	75	38	2	0.9	59	22	2	0.5	76	30	2	0.7

*See Figure I-A.

TABLE II-A

REACTOR BLANKET GAS SYSTEM
TRANSIENT PRESSURE -CALCULATIONAL PROCEDURE

Input: System Constants & Initial Conditions

Calculate m_T at initial conditions

Input: New volume of gas in gas plenum (perturbation)

Solve equations 20,21,22,23, &24 with previous conditions

Do two iterations* on V_{34} using equations 20,21,22, & 28

Calculate mass loss through vacuum breaker based on P_A, eq 18. Adjust equation 20& 21 for this mass

Do two iterations* on V_{12} using equations 20,21,23,& 29.

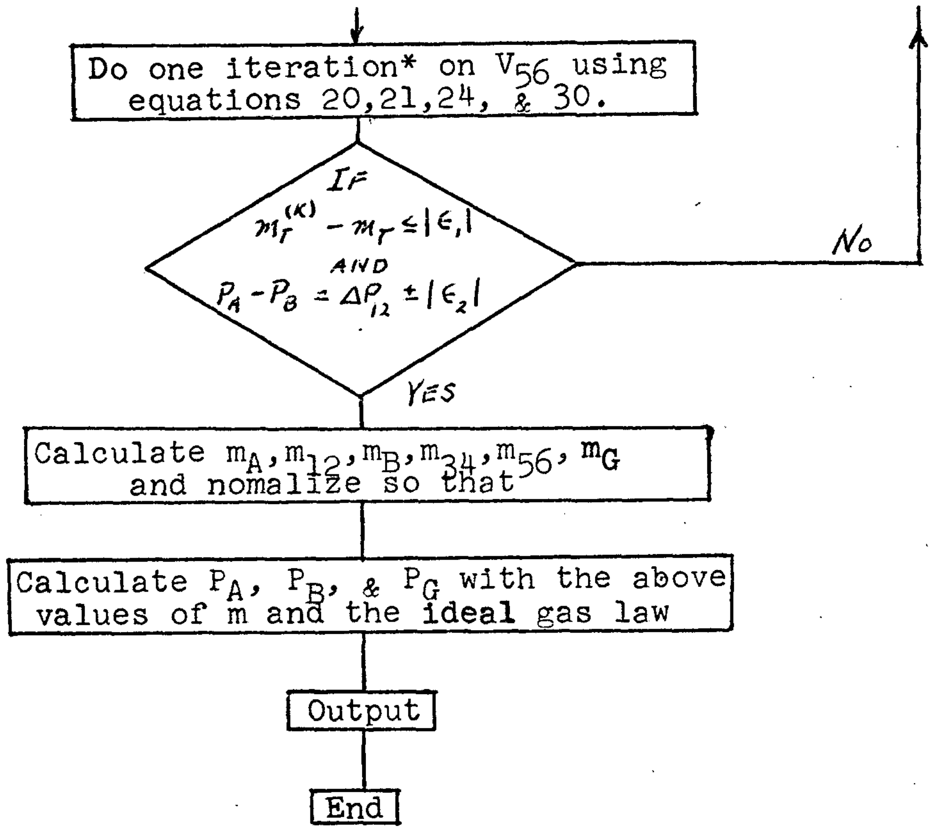
Calculate pressure at P_h based on V_{12} and P_A. Then calculate mass of gas vented or makeup at point h. Adjust equations 20& 21 for this mass.

(CONT'D)

* Apply relaxation factor to new estimate of velocity after each iteration.

TABLE II-A (CONT'D)

REACTOR BLANKET GAS SYSTEM
TRANSIENT PRESSURE - CALCULATIONAL PROCEDURE



* Apply relaxation factor to new estimate of velocity after each iteration.